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STEEL- U.S. STEEL
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Operational highlights of United States Steel Corporation (for brevity, here called U.S.Steel or USS)

In reading the first page of this one-leaf-book, you will have learned how three men, Andrew Carnegie, Charles M. Schwab and Judge Elbert H. Gary affected the early history of steel in America and the beginnings of the United States Steel Corporation.

When formed in 1901, it became not only the world's first billion-dollar corporation but the first steelmaking company to integrate the steps of mining its own materials, transporting them to its own mills, producing steel and distributing it widely.

Originally comprising the Carnegie interests and nine other companies, it was actually a "holding" company. Since then it has undergone continual steps of change, simplifying its corporate and administrative structure, adapting its operations to demands, and adding production units — all to better serve America's continually growing economy. In doing so it has held its number one position.

Major steps were taken in 1951-52 by merging five wholly owned subsidiaries to make the corporation an operational unit directly engaged in production and distribution of steel — and in related activities. Further streamlining occurred in 1964 with an administrative reorganization to combine operations of seven divisions (including mining and shipping) with others carried on directly by the corporation. Steelmaking plants were given four product groupings: heavy, sheet and tin, tubular, and wire. District offices were consolidated, reducing their number from 53 to 32. And the corporate capital structure was revised in 1966.

SCOPE OF PRODUCTION

U.S.Steel produces approximately one-fourth of the raw steel total in the U.S.A. It mines and quarries substantially all of its iron ore and limestone and produces most of its ferromanganese. Some of these are sold to others.

It mines more than half of the coal going into its coke ovens — making it one of the largest coal mining companies. It produces over 10,000 combinations of sizes, shapes and metallurgically different steels.

These range from all grades of plain carbon steel to high-strength, alloy and stainless steels; from low-strength ones for such as bottle caps, to high-strength constructional steels and on up to those for space-age uses that have a yield strength of over 350,000 pounds per square inch.

U.S.Steel also produces steels with coatings of other metals, paints and enamels. Most of these are shipped to manufacturers for processing (often in combination with other materials) into countless items of everyday personal, household, business and industrial use.

SCOPE OF OPERATIONS

Besides mining and processing raw materials at many locations, shipping a large part of them via its own fleet of cargo vessels, and the making of steel and steel products in 28 present plants, U.S.Steel is engaged in other related manufacturing operations through closely integrated subsidiaries and divisions.

These include:

X *Fabricating* structural steel and *erecting* steel buildings, bridges and other structures. *(see right)*

X Producing *coal chemicals* which are derived from gases and tars during conversion of coal into coke.

X Making of several kinds of *cement* including the type used with steel for reinforced concrete.

X Manufacturing *prefabricated homes* and building components utilizing steel.

X Manufacturing oil-field *drilling and pumping equipment* for the petroleum industry.

X Manufacturing *titanium* sponge and metal. Fabricating titanium products. Titanium is a light-weight, though extremely strong, corrosion-resistant metal with many space-age applications.

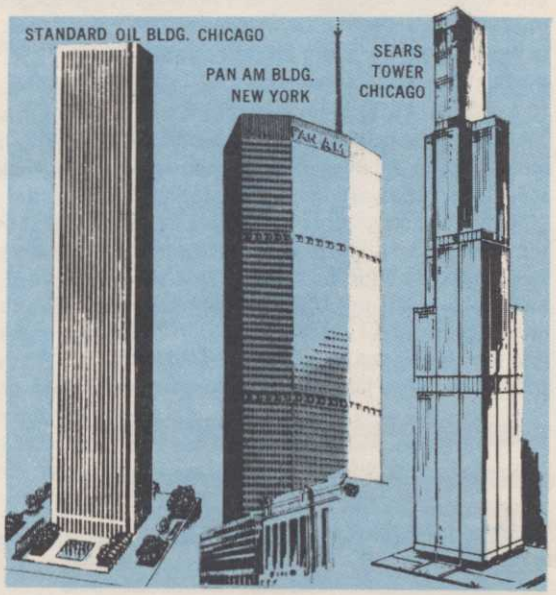
X The making of *many other products:*
Rails, wheels, axles, and trackwork accessories for railroads; pipe and tubes; wire fencing; steel and wire strapping equipment; drums and pails; galvanized ware; special forgings such as shafts for huge electric power generators; and a recent contribution to the packaging industry — a paper thin steel foil, strong alone or when laminated to other materials.

Additionally, U.S.Steel

operates *steel service centers* in 28 cities for the supplying of most of its products in relatively small quantities; maintains subsidiaries for the sale of its products in *foreign markets;* has a financial interest in a steelmaking company in Spain — and a steel-processing and fabricating facility in Italy. Other foreign interests include a manganese ore mining company in Africa and ocean transportation companies headquartered in the Bahama Islands — where a subsidiary has a cement plant

CONSTRUCTION BY AND WITH U.S.STEEL

USS has fabricated and erected (or fabricated steelwork for) many of the world's tallest buildings. An early giant is the 1250 foot high Empire State Building. It is interesting to note that constructional steels, developed through research of USS, are today so much stronger in relation to weight than steels available when that building was constructed in the early 1930s, that, with today's steels, it could have 115 stories instead of its 102 without a pound of increase in weight.



Here are some others:

The Sears Tower, Chicago — 1454 ft. (World's tallest)
The Standard Oil Building, Chicago — 1136 ft.
John Hancock Center, Chicago — 1107 feet
The Chrysler Building, New York — 1046 feet
Rockefeller Center, New York — 9 buildings, up to 850 feet
The U.S.Steel Building, Pittsburgh — 841 feet
Pan Am Building, New York — 808 feet
The Woolworth Building, New York — 792 feet
The Prudential Tower, Boston — 750 feet
The Terminal Tower, Cleveland — 708 feet

Over a dozen more of the world's great buildings could be named as well as unique structures like the Superdome in New Orleans, Houston's Astrodome, Pittsburgh's Civic Auditorium, and many of the world's greatest bridges.

RESEARCH

Pictured and discussed on a preceding page is the USS Research Center. Because of limited space, only a few of its many achievements can be mentioned here: Invention of an electrolytic process for depositing tin on a moving steel strip for the making of tin cans; development of the country's first commercial vacuum degassing unit, now operating; the first *continuous-continuous* slab casting facility developed in the U.S.A.; development of the first family of high-strength constructional alloy steels; thin tin from double cold-reduced tin plate; steel foil, thinner than tissue paper; the HY family of steels for nuclear submarines and other hydro-space vehicles; corrosion resistant steels like USS COR-TEN.

USS product development programs introduce new or improved products each year. In fact, because research has developed so many new processes, better controls, superior finishing mills and better utilization of raw materials, all steels today are NEW.

U.S.Steel will continue to place major emphasis on the many phases of research and development that will further scientific and technical advancement — benefiting everyone.

EMPLOYEES

A recent annual average of USS personnel is over 187,000. U.S.Steel is an equal opportunity employer as to race, sex, color, creed and national origin. This includes equal opportunities for upgrading, training and promotion — for which study and class programs are available to all.

Most employees are members of The United Steel Workers of America. USS is also party to over 100 collective bargaining agreements with over 30 other unions of which employees are members, though thousands belong to none. Generous pension programs plus insurance, savings, vacation and supplemental unemployment benefit plans are provided. USS safety programs in plants are so effective as to claim records ten times better than industry generally.

Additional copies of this piece are available to schools, libraries and other educational institutions at no cost. Write on Institutional stationery to:

EDUCATIONAL SERVICES, UNITED STATES STEEL CORPORATION, 600 GRANT STREET, PITTSBURGH, PA. 15230.

About three men of steel, a corporation, and a new building

You are probably aware of the importance of steel to our nation as well as in our everyday life. But you may not know how it all happened.

The purpose of this one-leaf-book is to tell the whole story so that it may be read with equal interest by both young and old alike.

It will take you from smelting of metals in prehistoric times through the fascinating development of the iron making processes and on into the many facets of the steel industry's remarkable growth.

Its beginnings in America date from only a little more than a century ago. Shortly after the close of the Civil War, a young man was starting on a road that would make him not only the outstanding leader in the steel industry but a millionaire who gave back his fortune to help millions of people.

Andrew Carnegie was born in Scotland on November 25th in 1835 and came to America with his parents at the age of 13. Having relatives in Pittsburgh, the very poor Carnegies settled there. A few years of schooling in Scotland was to be all that Andrew would have, for he immediately went to work in a cotton mill at a wage of $1.20 a week.

He was a bright boy and read all the books that he could borrow. Successively he became a telegraph messenger boy, a telegraph operator, then a clerk in the Pennsylvania Railroad offices. He saved every cent possible and began investing early.

By 1859 he was superintendent of the Pittsburgh division of the railroad; then during the Civil War, held a government job heading repair crews on telegraph lines. Soon after the war he bought a part interest in a Pittsburgh forging shop. By 1870 he had organized several wrought iron works. In 1875 his first steel plant, the Edgar Thomson Works, was operating, with a steelmaking genius, Capt. William Jones, in charge. By 1890 he owned two more and controlling interest in six others!

In 1893 he dropped wrought iron operations to concentrate on steel. In 1899 all his interests were brought together as The Carnegie Steel Company.

But at age 66 in 1901, Andrew Carnegie had had enough of business and wanted to retire and enjoy life. All of his interests were merged with many tin plate plants, several branch railroads, ore mines, and a fleet of ships to form the new United States Steel Corporation.

Some years before, he had begun a program of founding free public libraries and contributing to educational institutions. By 1911 there were formed Carnegie Institutes in Pittsburgh and Washington, D.C. and the Carnegie Foundation of N.Y. to administer giving $300 million for many forms of human betterment here and in Great Britain.

A total of 2800 public libraries, several medical schools and art museums benefited; Carnegie money supported research in radium by Madame Curie and in biology by Robert Koch.

Other research benefited (including the 100-inch telescope at Mt. Wilson Observatory). Founding the Pan-American Union and the Peace Palace at The Hague advanced world peace. Over most of the earth, Carnegie-endowed projects are continuing the advancement of knowledge and human betterment.

After "retirement", he lived in Scotland, owned a British newspaper chain, but came back to the USA in 1914, saddened by the advent of World War I and the failure of his strivings for world peace.

He authored eight books. His autobiography was published the year of his death, 1920, at age 85.

Charles M. Schwab and Elbert H. Gary

Carnegie acquired the Homestead Steel Works in 1883. Its superintendent was Charles M. Schwab. From then on, Schwab had much to do with the great advances made by Carnegie interests. In 1900 he became president of The Carnegie Company, then the world's largest producer of steel.

Prior to a testimonial dinner for Carnegie in 1900 with Schwab as main speaker, Carnegie had confided his desire to sell out and retire. And so Schwab dazzled the audience with his new operating concepts for the steel industry's future.

He had discussed them with Elbert H. Gary, (known as Judge Gary) president of the largest western steel firm, Federal Steel — and the Judge agreed: That one mill should make one related line instead of many products in many processes; that costs of transportation, then one-third of steel pricing, could be cut sharply; and that all the economies outlined would lower the selling price of steel.

The result was formation of United States Steel Corporation, which bought the Carnegie holdings for $400 million, naming Schwab as President and Gary as Chairman of the Board. Schwab resigned in 1903 to manage Bethlehem Steel; Gary held his Chairmanship actively until his death in 1927.

Largest in the industry since its beginning, the history of United States Steel Corporation has many "firsts". One is the custom, begun by Gary in the first annual report of 1902, of giving *all* facts and figures about the year's operations . . . a precedent soon followed by other corporations.

On the back page there is a brief history of U. S. Steel operations.

This Building for which ground was broken in Pittsburgh's Golden Triangle on March 15, 1967, is the Pittsburgh headquarters of U. S. Steel.

The triangular building is loaded with "firsts" — bold concepts and innovations. The most striking feature: 18 massive supporting columns extend the entire 841 feet of its 64 stories. They stand three feet out from the walls and, like the walls, are made of COR-TEN steel.

They are filled with 500,000 gallons of treated, pumped water for fire protection. Anti-freeze will protect the water from freezing in cold weather.

The columns connect to central core framing at every third floor. The "hat" structure on top ties core columns to the exterior ones, minimizing temperature change expansion-contraction; utilizing the exterior columns' resistance to wind loads.

The triangular form consists of three office space areas around a triangular service core containing stairs, elevators, connecting halls, telephone and all utility facilities, rest rooms and mail rooms. The mail is distributed by vertical conveyors.

The 48 passenger elevators are arranged so that each bank serves an average of ten floors — and there are ten moving staircases.

Two acres of plaza surrounds the building area of nearly one acre. There is an auditorium seating 350; restaurants on ground level and on the 62nd floor; inside parking for over 600 cars; a roof heliport designed to accommodate vertical take-off planes; a 63d floor centralized computor console to regulate mechanical and electrical facilities; stainless steel window frames to hold bronze-tinted glass.

Five kinds of steel are used in construction of the building. This is the Family of Steels concept developed by USS and uses the best, most efficient steel for each specific application. The one most in evidence, COR-TEN, pioneered by USS in 1933, combines strength with resistance to atmospheric corrosion and low maintainence cost.

Shown here is the change in appearance that is brought about by oxidation.

You are invited to visit us — inspect our new home — and view the picturesque Pittsburgh area for 50 miles in each direction from the 62nd floor.

This is a large steel plant, the Fairless Works of United States Steel Corporation, located on the Delaware River near Morrisville in Pennsylvania. Railroads bring in materials, move them between operations, and finally transport steel products to countless manufacturers across the nation and abroad.

Located here are some of the principal operational centers:

1. Main Office
2. Central Maintenance
3. Locomotive Repair Shop
4. Coke and Coal Chemicals Plant
5. Open Hearth Plant
6. Elevated Gas and Steam Lines
7. Blast Furnaces
8. Iron Ore Yard
9. Ore Unloaders and Conveyors
10. Sinter Plant
11. Blast Furnace Clarifiers
12. Power House
13. Soaking Pits
14. Slab and Bloom Mill
15. Blooming Mill
16. Hot Strip Mill
17. Bar Mill
18. Rod Mill
19. Sheet & Tin Div.
20. Galvanizing Mill
21. Pipe Mills
22. Electric Furnaces & Bloom Caster

Research is a vital arm of steelmaking. U. S. Steel has lead in scientific research since the establishment in 1910 of the industry's first research laboratory. In 1956, two former laboratories were combined to form U.S.Steel's Research Center a few miles east of Pittsburgh, shown above. Nearly 2,000 men and women are employed by USS in making major contributions to the science and technology of the world's steel industry. Some of these are listed in the USS story on the back page.

The exacting work of Dr. E. C. Bain (retired USS assistant executive V.P.) and his colleagues at the Fundamental Research Laboratory is credited with changing heat treating from an art to a science. One of the principal crystalline structures obtained from heat treating is named *Bainite* in his honor.

Recently installed at the Center is the Western Hemisphere's most powerful electron microscope capable of generating one million volts. It can reveal the internal structure of matter down to atomic dimensions. This super tool of science, pictured here, is helping in the search for superior steel micro-structures to meet the needs of tomorrow.

Alloying elements

We could not live as we do today were it not for special types of steel called ALLOY STEELS. Accounting for about 12 per cent of all American steel production, they do jobs plain steels cannot — such as providing the toughness to withstand constant friction or extremes of acids and heat. Examples: Ball bearings, airplane exhaust pipes.

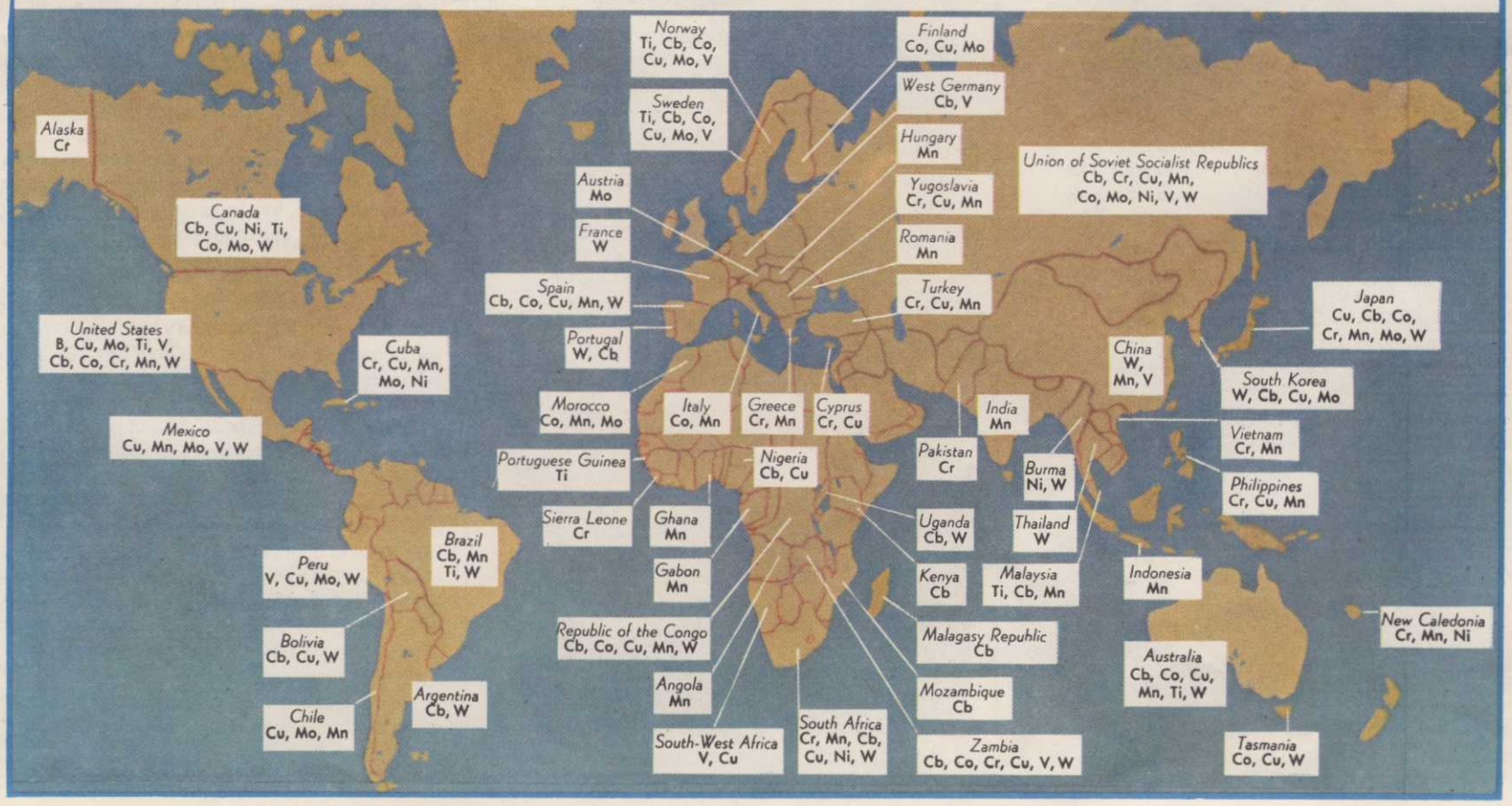
One alloy type, *stainless steel*, everyone uses daily. Such steels are made in electric furnaces by adding alloying elements to molten carbon steel, described on the inside pages.

Although our country has the three basic raw materials of steelmaking (see opposite), we are not amply supplied with the most useful *alloying elements:* chromium, manganese and nickel.

We must import these (particularly nickel) and many others from all parts of the world — as must most other steel producing countries.

The map shows how nations must depend upon each other for these alloy-minerals. Of course, this is also true of many other daily necessities of modern life. All of us, in our inter-dependence, are becoming more and more a part of "one world".

B — BORON **Cb — COLUMBIUM** (also known as Niobium — Nb) **Co — COBALT** **Cr — CHROMIUM** **Cu — COPPER**
Mn — MANGANESE **Mo — MOLYBDENUM** **Ni — NICKEL** **Ti — TITANIUM** **V — VANADIUM** **W — TUNGSTEN**



THE ONE-LEAF-BOOK STORY OF STEEL

PRESENTED BY United States Steel Corporation

EARLY MAN AND METALS

Sometime after man emerged from the Paleolithic into the Neolithic Age, he learned about metals. During this New Stone Age, about 10,000 years ago, he found *gold* in a pure state and used it for ornamental purposes. In searching for more, he came upon other soft metals, *copper* and *silver*, which he also treasured for personal adornment.

Some pre-historic metalsmith found that, *with beating*, copper could be hardened. With grinding

and polishing, the first metal knives, spearheads and skin-scrapers evolved — ushering in the Copper Age shortly after the year 6000 B.C.

Searching out this new treasure, man found that metals were intermixed with rocks and soil. With the aid of *fire*, he smelted down certain bluish-green rocks to extract pure copper. Reduction of copper is believed to have been first done in the Caucasus Mountains before 3500 B.C. — for by then both industry and trade with nearby lands were in full swing. Copper became a necessity.

The art of *casting*, developed in Mesopotamia, spread to India and the Orient. Utensils were followed by blades for weapons, implements and tools for clearing land, making boats and homes.

THE BRONZE AGE

Discovery was made in China (c.3000 B.C.) that *mixing copper and tin* produced a metal harder than either. It could be made so sharp that it was used for man's first surgical instruments. As secrets of alloying and casting filtered through to the Mediterranean, the Bronze Age began in earnest.

With all metals scarce and production costly, their possession was restricted to royalty, the priesthood, and for weapons of the royal armies.

The search for copper and the much scarcer tin spurred exploration and trade. Wars were fought for precious deposits or to take metals from the vanquished. Great empires arose: Egypt, Sumeria, Assyria, Babylon, Persia, and the Hittites.

THE ELEMENT, IRON

Five per cent of the earth's crust is iron . . . seldom found in pure form. Ancient legends tell that meteorite showers were known to Stone Age man in many parts of the world. Most meteorites are composed mainly of iron. Man found that their fragments could be hammered into usable shapes.

He came to prize the material above all other metals for the making of tools and weapons. The word for *iron* in nearly all early languages meant such as "stone from the sky" or "star metal".

But early *writings* cannot prove when or how iron ore was first *smelted* — for those languages became dead, lost, or their meanings clouded in translation. Outstanding metallurgists differ by 2600 years (4000 to 1400 B.C.)! Obviously, there are theories that ironworking preceded the Bronze Age. The truth may never be known.

Babylon's King Hamurabi (c.2050 B.C.) valued meteoric iron at up to twenty times that of copper. *A contention:* If iron smelting was practiced as early as 3500 B.C. in Egypt, why was iron so precious 2100 years later when three iron objects were placed in the tomb of Egyptian King Tut-ankh-Amen as among his most treasured possessions ?

THE IRON AGE

Opinion favors Chalybia on the Black Sea coast as birthplace of the true Iron Age. Chalybes are referred to by both Herodotus and Aristotle as *famous for ironmaking.* This preceded 1500 B.C. — for by then the Hittites (in what is now western Turkey) had learned of it from the Chalybes, soon developing a means of hardening that gave them an iron monopoly until conquered about 1200 B.C.

The Philistines had priorly developed the craft, bringing it to Palestine by 1350 B.C. In the Old Testament iron is mentioned ninety-five times (and steel, four!) from Genesis with Tubal-cain as *"an instructor . . . in iron"*, in Judges telling of the Canaanites routing the Israelites with nine hundred *Hittite-like chariots of iron*, and on to

records of axes, saws and harrows of iron in the reign of David (c.1000 B.C.). *Seemingly*, 1500 B.C. *may be taken as the start of the true Iron Age.*

IRON MAKING

The metalworking crafts were indeed ancient. There were guilds with closely guarded secrets. And revered gods — such as Vulcan and Brahma.

So smiths had been smelting metals long before iron came along . . . and at first used similar means with the new metal. They cooked iron ore with charcoal in a shallow, covered pit — often set into a hillside facing prevailing winds to have natural drafts heighten the fire's heat. Later, animal skin-bellows, hand or foot-worked, were used to make constant blasts of air, raising the temperature to around 2200 degrees Fahrenheit.

The hot mass, removed at a point of sponginess, was beaten to remove cinders; quenched *(cooled)*, reheated and beaten repeatedly to compact the structure of the wrought iron mass, still malleable for later final shaping on an anvil.

If the resultant iron absorbed from the bed of charcoal the right amount of carbon (under one

half of one per cent) and was properly quenched, it became right for shaping and sharpening into tools and weapons. But most of such wrought iron forging was by "rule of thumb". The Iron Age came into its own as controls were developed and smelters learned to add a *flux* of crushed shells or limestone to form a *slag* that absorbed much extraneous matter. Too, they had to perfect methods of *quenching, tempering* and *carburizing.* Carburizing means adding carbon to the surface layers so that with heat treatment the outer shell would be hard while the inside remained relatively soft.

As knowledge of the craft spread over the then known world, many variants of the techniques were developed and furnaces enlarged. Iron products in some areas had higher degrees of excellence than in others, some achieving the properties of steel.

SPREADING OF THE IRON AGE CULTURE

Iron was manufactured in India by 1000 B.C. and Chinese records date from about the same period. Romans learned from Greeks and Phoenicians; both brought iron know-how to the Gauls. It came up the Danube and spread through Europe; via Celtic invasions to Britain, the Early Iron Age there dating from 450 B.C. Plowshares, brought into Britain by the Belgae, initiated agricultural revolutions — later extended by Anglo-Saxons.

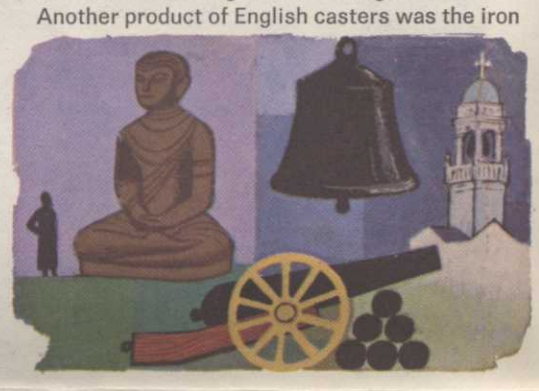
CAST IRON AND PIGS

Unintentionally, early smelters often produced *liquid iron* because the ore, heated to about 2400°F, had absorbed from the charcoal *too much carbon* (2.5 to something over 4 per cent). The solidified chunks were discarded as too brittle. Though the smelters knew about casting liquids of other metals, most did not deem the casting of iron as being worth the doing.

But some did. Writings (European and Chinese) of the sixth century B.C. tell of iron poured into clay moulds for casting statuary. At this time there was cast in China a statue of Buddha over sixteen feet in height — and many fine Chinese examples exist from around 200 B.C.

In Europe, the craft, seeming unessential, died out for many centuries. A huge revival resulted from demands for church bells during the era of seventh century A.D. cathedral and church building. Though it began first in Italy, England soon became the main center. There, thousands of bells were to be cast during the Middle Ages.

Another product of English casters was the iron



cannonball. And iron cannon, first cast in 1550, soon became one of their principal products of manufacture and export. Other cast iron items were coal stoves, kettles, pots and cogwheels.

For *large* objects, metal was poured directly into moulds. But for *smaller* objects, there was developed around 1700 a process whereby iron was flowed into a main sand-trough, with smaller ones on either side, to solidify for re-melting later. The shape was seen to resemble a sow with a litter of suckling pigs. Hence, the term *pig iron.*

Pigs became important, but not only due to storing for future use. It was found that by re-melting in a certain way in charcoal, they could be converted into *wrought iron.* And in France, *malleable iron* was made by imbedding pig iron in iron ore and heating for several days.

From these came the standard form, the plain *iron bar*, for re-working by the local blacksmith into horseshoes, hay-forks, sickles, bolts, nails, and countless other products.

OF FURNACES — AND WATERPOWER

The furnaces gradually grew taller . . . the four-foot *Catalan* type of eighth century Spain yielding some 350 pounds of metal in a five-hour heat. By building taller, up to an average of twelve feet, smelters of the Rhine valley in about the year 850, produced almost double the Catalan yield in their furnaces called *stuckofens.* But that was about the limit of production for manually operated bellows.

The solution was *water power.* Applied to iron-making in the early thirteenth century, it was first used to operate bellows *(two for a continuous blast of air)*. As they grew larger, so did furnaces. In about 1500, water power was applied to operation of a mechanical hammer for beating iron, its tilt-action equaling the work of twenty men.

So now an iron works should be located at the edge of a fast-flowing stream or river. But, due to high transportation costs, it also had to

be near sources of timber (for conversion to charcoal), limestone, and iron ore. Moves came slowly.

THE USE OF COKE

In the early 18th century, British forests were being denuded by rival needs of timber for ships and buildings as against making it into charcoal.

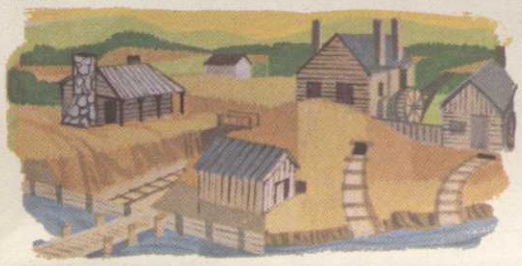
There had been many attempts to solve the problem by the use of coal. Finally in about 1710, a young malt-mill builder, Abraham Darby, familiar with the use of coke in the brewing industry, applied it to iron-making successfully. But efforts of his lifetime and almost all of his son's were expended before real acceptance in England of coked-iron finally came about in the mid-1780s.

And, as you'll read later, it was to be another half century before its use began in America.

IRON IN AMERICA

By the year 1640, over 20,000 settlers had come to New England. Though most had brought precious iron-axes, guns to shoot game, and pots for cooking food, more were soon needed. The few small iron works (using ore from local bogs) could not fill the needs, so these products had to be imported from England. John Winthrop, later Colonial Governor of Connecticut, stepped in to solve the problem.

He arranged English financing and had materials for constructing an iron works shipped in 1643 — but when set up it would not make iron! In the year following, a new works under management of Richard Reader, was built at Saugus, north of Boston, and became the first to produce iron successfully. With about 100 workmen, annual tonnage gradually



rose from 200 to 600. *(An exact replica of the Saugus Iron Works was built in 1954 through efforts of the American Iron and Steel Institute. It stands today as a monument to the American steel industry).*

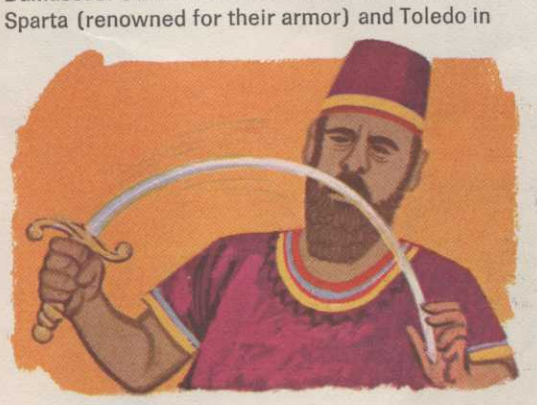
Its skilled workers, moving to areas north and south, set up other vitally needed works to serve the fast-growing Colonies. When deposits of rich ores were found, particularly in Pennsylvania, "Iron Plantations" were formed during the 1770s — the largest at Hopewell (Pennsylvania) with 1200 inhabitants. Here and at other plantations, arms, shot and cannon were made for the Colonial troops of the Revolution. The most famous of these, Valley Forge, was among many destroyed by British

troops in the war's early years to weaken the fighting power of General Washington's armies.

Early in the 1800s, steam power came into use, replacing water-wheels on which the American iron industry had depended. This was a timely advance because more and more iron was needed for boilers, locomotives, rails and bridges for the accelerated western movement of a rapidly growing nation.

THE BEGINNINGS OF STEEL

As we have seen, some forms of steel had been made since early times. One called "wootz", made in India in the third century B.C. was shipped to Damascus in Syria, to be made, over centuries to come, into the famous, supple and sharp swords of Damascus. Other ancient steel centers were in Sparta (renowned for their armor) and Toledo in



Spain, also famed for swords. And some steel had been developed in England over the centuries.

But all methods of making steel were much slower and more costly than the making of iron. This was also true of steel made in the few small plants of early America. With our westward expansion, as trains grew heavier and factory machines turned ever faster, it became evident that a tougher metal than iron was sorely needed. Even sturdy bridges of iron had been collapsing at an alarming rate — here and abroad.

ENTER: MR. KELLY AND MR. BESSEMER

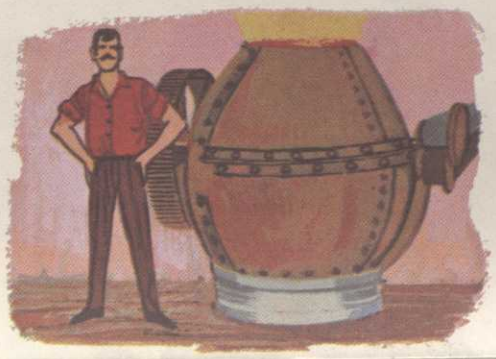
Fortunately, there had been experimental work going on both here and in England. A young American, William Kelly, had ideas that he began to develop in 1847. He first tried to eliminate the use of charcoal with an air boiling process; then worked on a thesis that blowing hot air *through* the molten iron would give the extreme heat needed to produce steel rapidly.

In his own iron plant, and later secretly (for he was being called insane even by his own father), he made convertor after convertor during the years between 1851 and 1856. None of these attempts being entirely successful, he held off applying for a patent until reaching perfection.

Meanwhile, an English inventor, Henry Bessemer, had ideas much like those of Kelly. After many false starts, he brought the process to a demonstrable point, secured English patents in 1855 *(American a year later)*, built his own works, and began operations in November of 1858.

Another Englishman, Robert Mushet, had been doing similar experiments with a German-invented alloy of iron, carbon and manganese called *spiegeleisen* — and not only produced steel but had his method patented in both England and the U.S.A.

While these developments were going on in Europe, our stubborn Irishman, Kelly, learned of Bessemer's patent just as he brought his process



to perfection in 1857. Nevertheless, he applied for a patent. Not only was it granted but he was also given an interference with Bessemer's on proof of prior work. But before Kelly could begin production, he was caught in the financial panic of 1857 and his business went into bankruptcy!

He moved operations to the Cambria Iron Works at Johnstown, Pa., built a convertor and ran trial heats. Having no money, he sold patents (but held royalty rights) to ironmasters Ward and Durfee — who organized the Kelly Pneumatic Process Company and obtained American rights to Mushet's process. In 1864, at their Wyandotte, Michigan plant, the first U.S.A. commercial pour of "Bessemer" steel was made. From those ingots, America's first steel railroad tracks were made in 1865 at the North Chicago Rolling Mill.

Meanwhile, another American firm was producing steel under Bessemer patents. The two companies combined — and the pneumatic steel process came into full production. 1867's 3000 tons rose by 1880 to one million, for the first time America's production exceeded Great Britain. Though the new process was known by the Bessemer name, Kelly came out with royalties totaling 450 thousand dollars!

FUELS AND ORES

Coke did not come into use as our ironmaking fuel until 1835 . . . over a century later than in Europe. Reason: The supply of timber for making charcoal seemed endless. But once started, the use of coke increased so rapidly that, by 1869, coke-produced iron finally exceeded that of charcoal. The use of coke was soon to become universal.

As to iron ores: The quality of local ores varied and costs mounted as inferior ores were shipped from greater distances. A solution came with discovery of good quality ores in northern Michigan in 1844. The Sault Ste. Marie locks between Lakes Superior and Huron, completed in 1855, led to the development of the great Mesabi iron range. The mines supplied the steel industry with high grade ores for almost 100 years.

THE OPEN HEARTH FURNACE

Shortly after the Bessemer process began its domination of the American steel industry, a rival process came on the scene . . . the Open Hearth.

One difference between the two methods was that the Open Hearth is a *regenerative gas furnace* that pre-heats air for combustion. The hot air uniting with fuel caused greatly intensified heat.

Two brothers named Martin had developed the idea in France. Two German-born brothers named Siemens, then English citizens, working along the same lines, contributed the *regenerative* feature. In 1864 this brother-combination perfected the process. In Europe it was called *Siemens-Martin* When it was brought to the U.S.A. in 1870, it was called *Open Hearth* because of its shape.

By 1900 its output equaled half that of the Bessemer method — and in 1908 exceeded it. The drop of the Bessemer process to today's near-zero was caused by several superior features provided in the Open Hearth process: Its greater capacity, its controls for varying chemical specifications, and its use of greater amounts of scrap. The process gained more efficiency as the years passed — due to a lot of American ingenuity.

THE MAKING OF STEEL

THE RAW MATERIALS

COAL is baked to become COKE. IRON ORES are blended according to degrees of purity. Crushed LIMESTONE is the fluxing agent. Each is loaded into a SKIP CAR for its trip to the furnace top.

THE BLAST FURNACE

This 250-foot-high monster extracts iron from iron ore. SKIP CARS dump raw materials into the top of the furnace, a steel shaft lined with water-cooled brick. Hot air from the stoves is blasted into the furnace's base, where it burns the coke and generates gases and heat required to separate iron from the ore. The molten iron settles on the "hearth" or bottom. Here the limestone combines with impurities in the iron and forms SLAG — which floats on the liquid iron. Every 3 to 6 hours the furnace is "cast" and iron and slag run into ladles or ladle cars for delivery to the steelmaking plants for further processing.

3

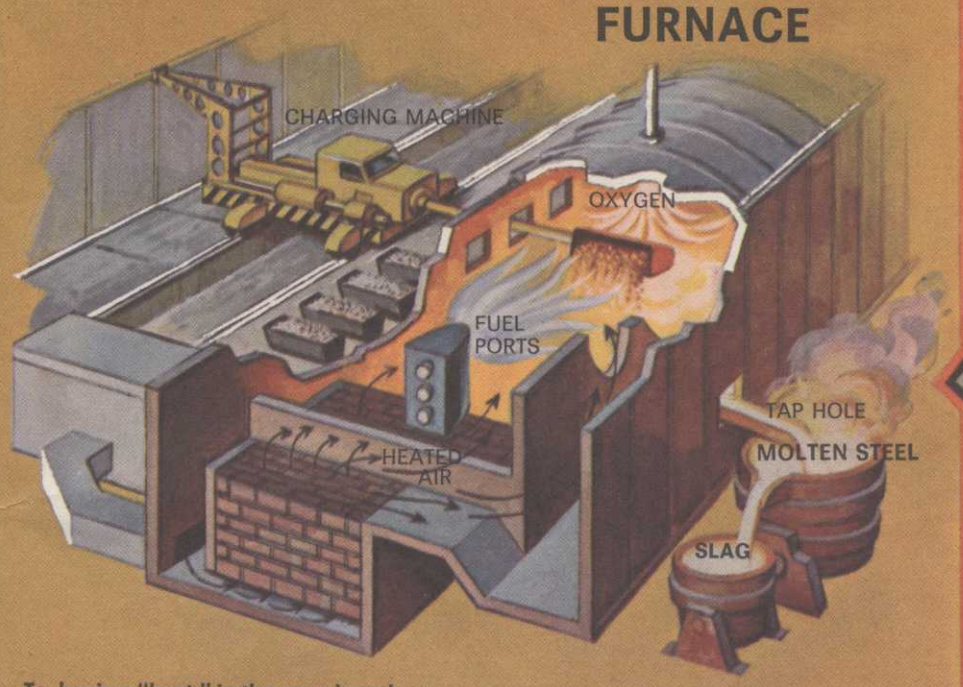
Molten steel is usually made into its first solid form by turning it into INGOTS — a process called TEEMING. A filled ladle is carried by a crane to a row of ingot molds. A valve in the bottom is opened, filling each mold to its brim. After the liquid steel has solidified it is called an ingot. Then molds are lifted (STRIPPED)

Believing that THE PROGRESS OF MAN IS THE PROGRESS OF STEEL, and that its story should be known to all, this one-leaf-book is p

MOLTEN IRON, 2500-degrees hot, comes from the largest blast furnaces at a rate of over 7000 tons a day. Oxygen has been removed but there remain impurities, particularly carbon, which make it brittle. Steel-making, essentially an iron-refining process, is accomplished by the three methods shown below. Each uses oxygen in varying degrees. Each of the furnaces is lined with heat-resistant materials. Batches of steel may be for differing purposes — one for refrigerators, one for car fenders, and so on.

The term SCRAP means no-longer useful steel from old automobiles, machinery, pipe, railroad tracks, and the like; also steel trimmings from mills or from product manufacturing. Its use in all steel-making methods conserves natural resources since EACH ton equals a ton of molten iron that would use nearly THREE tons of raw materials to make.

2-A OPEN HEARTH FURNACE



To begin a "heat" in the open hearth process, the furnace is "charged" with scrap, iron oxides (ore), and limestone. An operator feeds boxes of materials in proper proportions for each charge, dumps and withdraws the boxes — then moves the charging machine to load the next furnace.

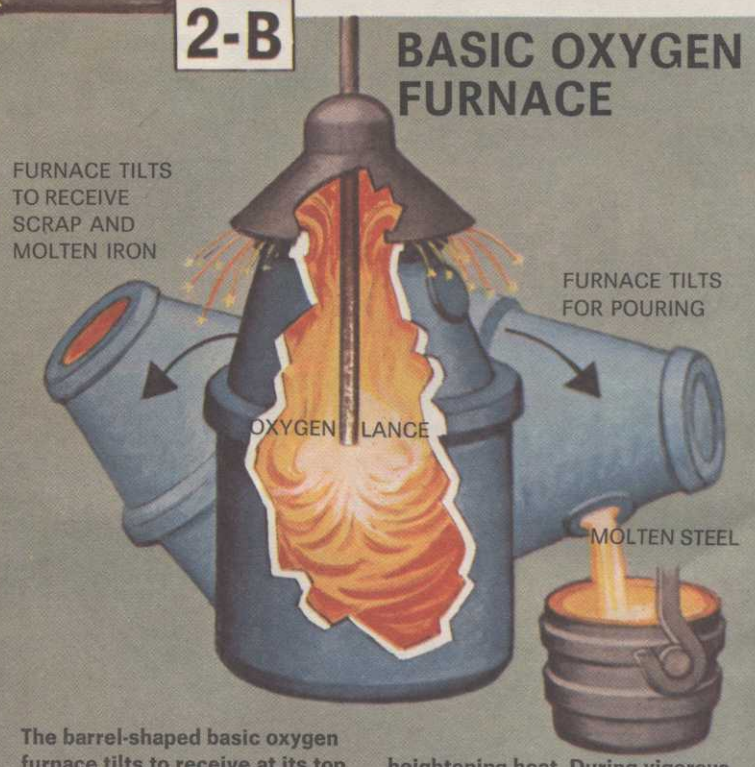
Inside, tongues of flame produced by oxygen combined with natural gas or liquid fuel, heat the charge for up to two hours. Only then is molten blast-furnace iron poured in (60 to 70 per cent of the mix).

The boiling mixture is cooked for 6 to 10 hours. The largest furnaces handle charges of over 550 tons total.

Oxygen burns out some impurities. Others, soaked up by the limestone, form a SLAG that floats on top. Steel chemistry is constantly checked.

To TAP the furnace, a "rocket" is fired to open a plugged-up hole in its side. The white-hot steel gushes out into a ladle as the slag flows into another.

2-B BASIC OXYGEN FURNACE



The barrel-shaped basic oxygen furnace tilts to receive at its top carefully measured amounts of scrap (around 25 per cent) and molten blast-furnace iron.

The furnace is turned upright, and a cooled "lance" is lowered near to the charge surface. Lime and other fluxes are added as pure oxygen gas is blown at very high pressures through the lance for 20 minutes, oxidizing impurities producing carbon monoxide gas, heightening heat. During vigorous boiling action, samples are taken.

After the lance's withdrawal, the furnace is tilted downward to pour the molten steel. Even in large furnaces producing 200 net tons, the whole operation, from one charge to the next, may take only 50 minutes. It is easy to see why this young process has become so popular with American steel producers.

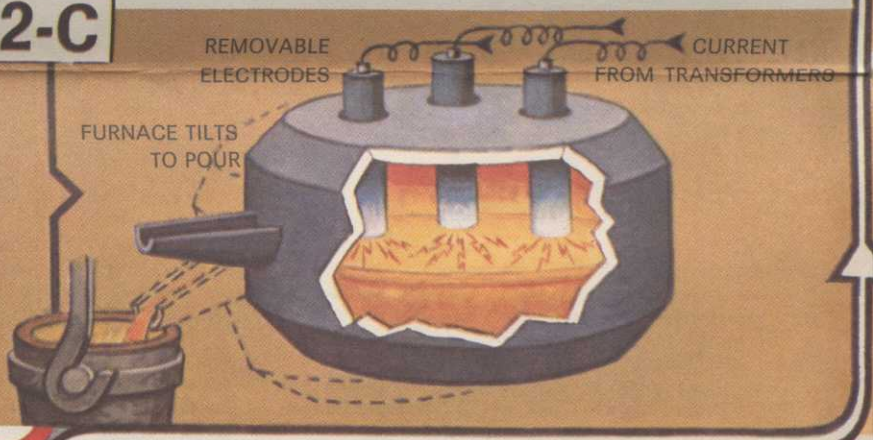
2-C ELECTRIC FURNACE

This is the only method that does not use molten iron from the blast furnace. It makes molten steel directly from scrap and other materials.

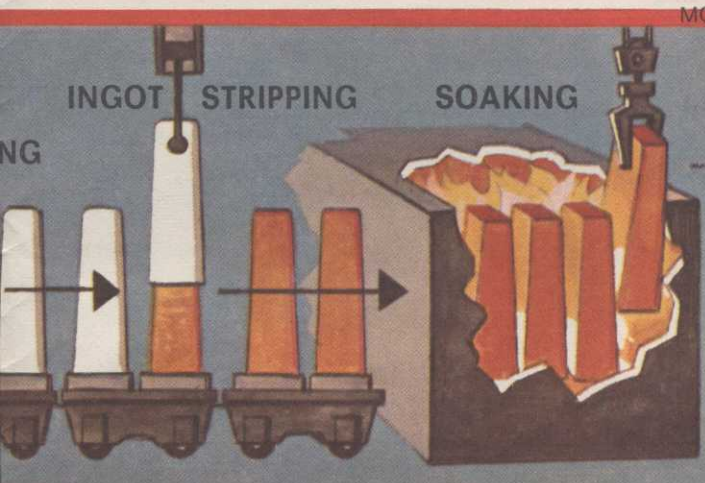
It can produce all kinds of steel — but because of its precise controls, is used principally to make ALLOY steels. (See preceding page). Because of exacting formulae, scrap is sorted into as many as 65 types for loading into the base of the furnace. Then the huge electrodes are lowered to just inches above the scrap.

The electric current, slowly at first, then faster and hotter, shoots lightning-like arcs to melt the scrap. Carefully measured alloys are then added, differing for each kind of steel made.

Gaseous oxygen, iron ore, (or both) burn out some impurities; others are carried off by various fluxes. During several hours of cooking and stirring, test samples are constantly taken. To pour, the whole furnace is tilted.

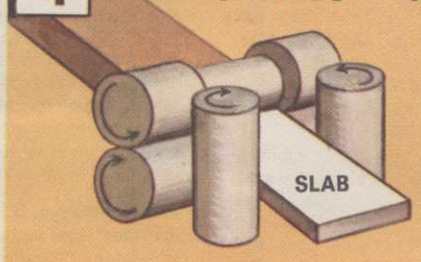


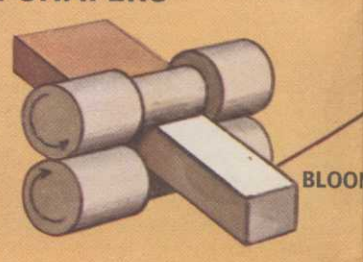
MOLTEN STEEL



from the ingots with tongs. Ingots cool fast on the surface but slowly inside. So they are placed in PITS and "soaked" in heat until temperature is uniform. A crane transports them to ROLLING MILLS.

4 ROLLING MILLS — THE SHAPERS





In the Primary Rolling Mills, hot ingots are squeezed into shapes under great pressure. In the Semi-finishing Mills, three basic forms are produced: SLABS, BLOOMS and BILLETS. In rolling slabs, ingots are pressed to about 32 feet long, 10 inches thick, and up to 7 feet wide by a series of rollers controlling all dimensions.

STEEL GOES WEST

Following the Civil War, steel rails were aiding the western migration of homesteaders. They used steel plows to turn the sod — and the mechanical reaper made possible harvesting the big crops, particularly wheat. But it was mainly *barbed wire* (though but one of 150,000 types of wire eventually recorded), that was to change the West from open cattle range land into farms and communities.

Pointing up the importance of steel in the western movement was the dramatic meeting of rails of the Central Pacific and Union Pacific railroads at Promontory Point, Utah on May 10, 1869. For the next thirty years most American steelmaking (8.5 million tons in 1899) was for rails.

As steel was helping populate the West, it was also affecting the lives of other Americans. The steel skyscraper, originating in the 1880 and 90's "Chicago School of Architecture", was to change the face of cities. The bicycle craze of the 90s was responsible for the perfecting of *seamless* steel tubing. And not long after that, the automobile grew out of the horseless-carriage stage into the beginnings of the giant industry of today, one of the largest single consumers of steel.

THE TWENTIETH CENTURY

Since 1900, the American steel industry has seen tremendous expansion geographically. As of today, steel is produced in 35 of our 50 states.

It was early evident that striving to keep steel prices down was paramount. Also evident: America's future industrial needs could best be served by a more complete integration of operations. After the U. S. Steel Corporation became, in 1901, the world's first billion dollar corporation, it was the first one able to mine and quarry its own raw materials; to operate means of transporting them to mills for production of steel ready for shipment in many forms to manufacturers.

The growing automotive and building industries helped foster growth of other large steel firms with integrated operations. A rapidly expanding economy demanded more and more steel and the industry responded with constant development of mines, mills, methods and technology. The U.S.A. soon became the world's largest producer of steel. In 1974, annual production was more than sixteen times greater than that of 1900.

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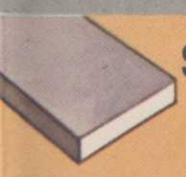
COATING AND FINISHING

Certain end-uses of steel require that it be coated for protection against corrosion or to give it an attractive surface. Coating with aluminum (aluminizing) or zinc (galvanizing) are examples. Steel is passed through baths of molten coatings. Some metallic coatings are applied by a vacuum process.

In TIN plating, mainly used for "tin cans" (actually nearly 99 per cent steel), acid treated steel is plated on both sides with pure tin by "electrolysis" in varying thicknesses depending on the end use.

STEEL PRODUCTS are all around us. The sheet of paper you now hold was made on steel machines and was printed on presses of steel. Below are but a few of many thousands of products made from the basic forms of slabs, blooms and billets.

SOME OF MANY THOUSANDS OF STEEL PRODUCTS



SLABS

A 32-foot-long slab, 10 inches thick and up to 7 feet wide, moves through rolling at up to 44 miles per hour. It can be extended 100 times in length and reduced over that much in thickness. Such flat steel, when thicker than one-quarter inch, is called PLATE. Thinner forms are STRIP or SHEET, which, according to end-uses, may be rolled down to one-hundredth of an inch — or to less than half that for FOILS.

PLATE, SHEET AND STRIP

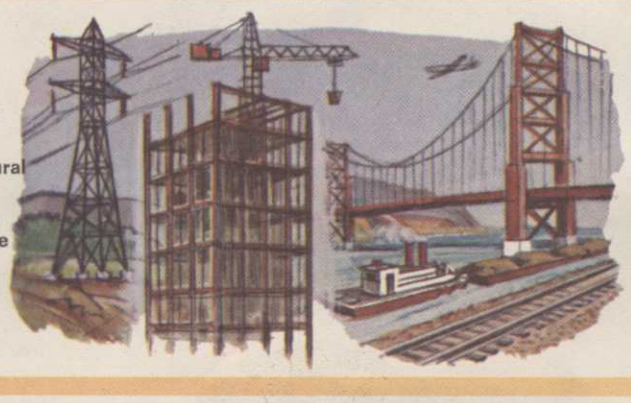
Transportation ranks first in this category. Included is a goodly amount of the over 100 KINDS of steel in autos, trucks and buses. Airplanes, ships and railroad cars all use plate, sheet and strip. In the home: stoves, refrigerators and washing machines. Much is used in oil refinery tanks, farm and other machinery — and for a lot of roofing. Sheet and plate are also used to make WELDED pipe and tubing.

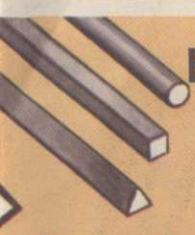
BLOOMS

As told below, blooms are square shaped bars of steel of varying sizes. They are shaped into girders and beams for structural purposes by passing the white-hot bloom through a series of grooved rollers that eventually produce the desired end-shape, be it I, H, T, or other. Rails for railroad track are made similarly.

STRUCTURAL STEEL AND RAILS

Every city dweller is conscious of the many new steel buildings, ranging from shiny ones sheathed with stainless or porcelain-enameled steel to those of russet-toned USS COR-TEN steel. Structural steel is used for the frames of buildings, for television towers, electrical transmission towers, and the many great new bridges. Similar forms are used in making cranes, ships, machinery and railroad tracks. Much new track is welded end-to-end to make continuous rails many times longer than the usual 39-foot lengths.



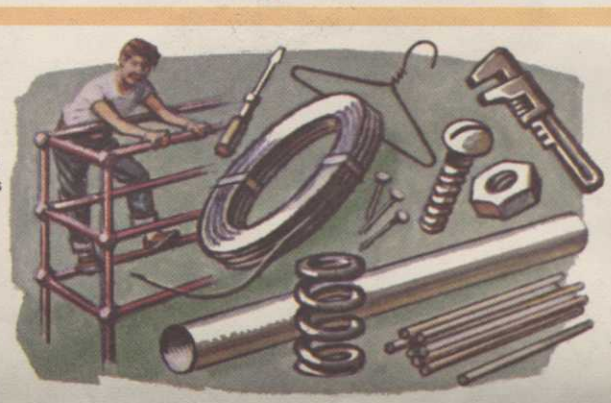


BILLETS

are further reduced blooms that are formed between sets of rolls with matching grooves to make BARS and RODS in round, square, or other shapes in varying sizes. Round billets are used to make SEAMLESS PIPE by a combined hot spinning, piercing process. WIRE is made by "drawing" a rod through a DIE with a hole smaller than the rod; the smaller the die hole, the thinner the wire.

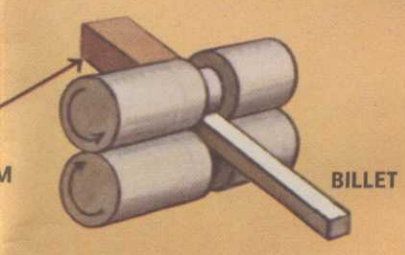
BARS AND RODS

These forms are used in automotive parts such as piston rods and brake connections . . . in fact, most machinery uses them. Other uses include the making of tools like screwdrivers and wrenches — as well as nuts, bolts. rivets and screws. Bars give reinforced concrete its great strength. Pencil-thick rods are drawn into hundreds of different types of wire — ranging from strands for heavy cables, fencing and screens to everyday objects like nails, needles, pins, paper clips and clothes hangers — plus the many kinds and sizes of springs.



COLD ROLLING

involves great reduction in thickness, sometimes down to under two-hundredths of an inch, for such end products as TIN PLATE. Coils from hot-strip mills, conditioned by acid baths, are cold-rolled, followed by a heat-treating process called "annealing" to impart the proper ductility for final rolling.



The Blooming Mill shapes the hot ingot into square forms of varied sizes. These may go on for further processing into many kinds of structural shapes — or for size reductions into smaller forms called BILLETS (See above).

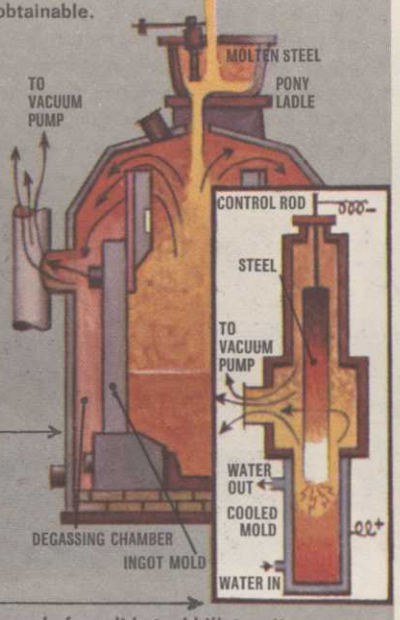
VACUUM PROCESSING

Steels for critical applications such as for space and nuclear requirements are often processed in a vacuum to impart properties not otherwise obtainable.

PURPOSE: To remove from molten steel such gases as oxygen, nitrogen and hydrogen to make high purity steels.

In one method of VACUUM DEGASSING, conventionally melted steel, released from a furnace ladle into a "pony" ladle, goes into a vacuum chamber. Here it is broken into droplets and the unwanted gases are drawn off before the metal becomes solidified in ingot form.

VACUUM MELTING provides even higher purity than DEGASSING. A method shown here is a vacuum-arc "consumable electrode" process.

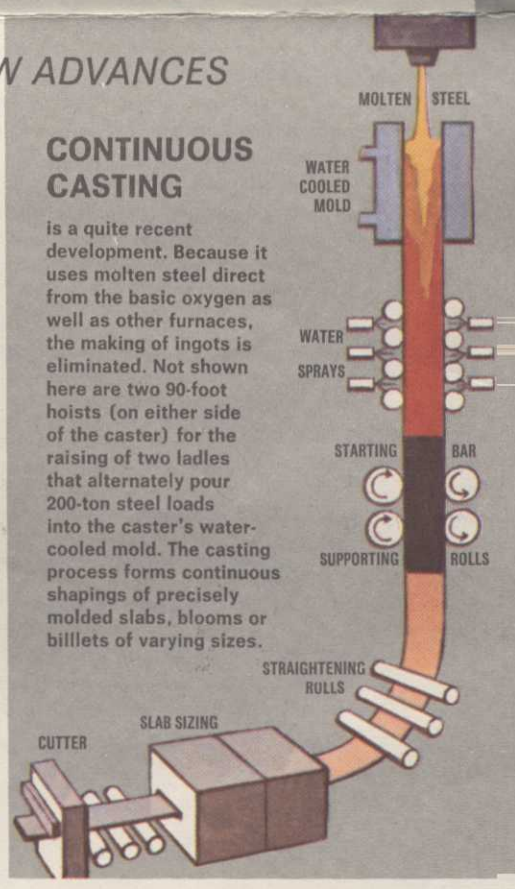


An electric arc remelts the end of a solid steel billet as it is lowered like a giant electrode into a vacuum chamber. Harmful gases are removed and the remelt process eliminates most of the nonmetallic inclusions from the billet.

TWO NEW ADVANCES

CONTINUOUS CASTING

is a quite recent development. Because it uses molten steel direct from the basic oxygen as well as other furnaces, the making of ingots is eliminated. Not shown here are two 90-foot hoists (on either side of the caster) for the raising of two ladles that alternately pour 200-ton steel loads into the caster's water-cooled mold. The casting process forms continuous shapings of precisely molded slabs, blooms or billlets of varying sizes.



ADVANCES IN TECHNIQUES

Automatic Rolling of Sheet Steel. In early times steel was produced in bar forms. But demand for long, thin, wide sheets was insistent — and though attempts were made, the best produced prior to 1890 was 7 inches wide by 100 feet long. In 1936, the width was increased to one yard. Gradual improvements now enable the hot-strip rolling mill to produce continuous sheets up to 2000 feet in length, 26 to 96 inches wide, and in any desired thickness.

Improved cold-rolling techniques have kept pace and steel has been rolled extremely thin — less than 0.001 of an inch thick.

Alloying was the invention of an Austrian in 1855 — though patented and first put to use in England as *Tungsten Steel* in 1868. Among its first beneficiaries were machine tools. In 1895, a means of heat-treating was developed in America, which was to increase the cutting power of tungsten steel many-fold and exert a profound influence on world-wide industrial development.

Then came *manganese-steel* for wear resistant applications. In the 1890s, steel combined with *chromium and nickel* was developed for projectiles, guns and naval armorplate. In the 1900s this type was put to many uses including the earlier autos and airplanes. Alloy steels were then very costly — but with the advent of the electric furnace, alloy steel products were soon being made for general usage at a much lower cost.

One of these is the glamour metal of many uses, *stainless steel.* Its main alloy, chromium, provides its qualities of corrosion, heat and rust resistance. *(See more about alloys on preceding page).*

The Electric Furnace. Experiments using the electric arc *(developed in 1800)* for heating iron-reduction furnaces had been going on in Europe since 1878, with final success in 1908 in Sweden.

American development of these ideas was first applied to *steelmaking* between 1902 and 1905. Progress was delayed by the limited supply and high cost of electricity and failures in making carbon electrodes to carry sufficient power. In 1911 the electric furnace finally began production here. Increased usage has been steady, accounting for over 19 per cent of American steelmaking in 1974.

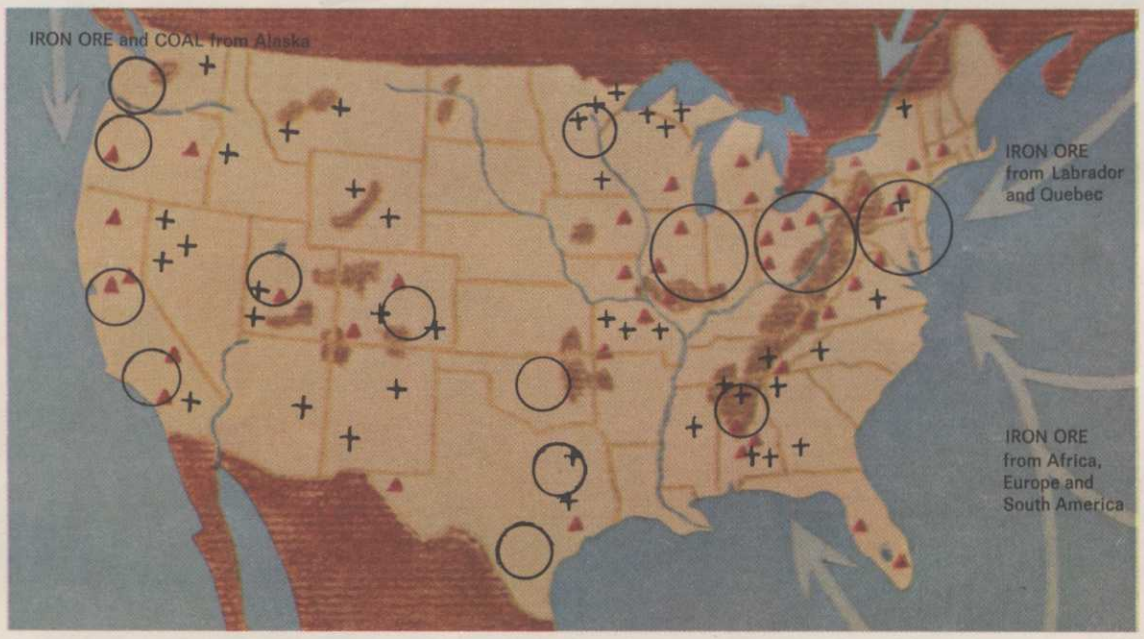
The Basic Oxygen Furnace

Perfected in the early 1950s, it has made steady gains over the long dominance of the Open Hearth Furnace. Advantages of oxygen as a blowing agent had been known since Bessemer days. Finally, production improvements made commercially pure oxygen low in cost and also available in quantity. Many times faster than the Open Hearth, it is now making over half of America's steel. Predictions are for nearly two-thirds soon.

Recent advances

Two of the most important (see above) are Vacuum Processing — so vital to our space program — and the Continuous Casting method, both results of years of research and development. Scientists are constantly at work to perfect means of producing ever better steels to meet the challenges of the immediate and near-future.

Basic ingredients of Iron and Steel



Iron ore, coal and limestone; these are the basic raw materials used in making both iron and steel. Fortunately, supplies of all three are plentiful in the United States. Though steel is made in 32 of our 50 states, only the larger centers of production are circled on the map. It is noticeable that each is close to sources of raw materials — a good reason why the largest centers range eastward south of the Great Lakes and into the Alleghenies. But those to the south and west are increasing.

IRON ORE

Iron is an element forming 5 per cent of the earth's crust. Its chemical symbol, *Fe* is from the Latin word for iron, *ferrum.* The most common type of ore, *hematite,* has a reddish color. Ores found near the earth's surface are mined in "open pits", the largest being on the Mesabi Range in Minnesota.

Before shipping, impurities are removed by various methods called *beneficiation*. Lower grade ores like *taconite* are found as part of rock formations at and below the earth's surface. It is crushed to small fragments and impurities removed by means such as magnetic separation. The particles, now 65 per cent iron, are rolled in drums to form marble-sized pellets that are heated for hardening.

Following treatment, ores are transported by rail or truck to a nearby port and loaded into holds of vessels up to 900 feet long for trips down the Great Lakes to the many mills. Here the ore is stored in mountainous piles awaiting use.

COAL

has been, and will remain for some time to come, the world's chief source of power and heat. The United States has half of the known deposits in the world, mining more bituminous coal than any other nation — well over half a billion tons yearly (equal to 100,000 train loads of 100 cars each).

Coal was formed thousands of millions of years ago from the wood of ancient forests. In succeeding eras of time they were covered by water, sand and soil which exerted great pressures, causing coal to be formed among alternating layers of rock in *seams* sometimes over ten feet thick.

Of several different kinds, *bituminous* (soft) coal is 100 times more prevalent in the U.S.A. than the hard *anthracite* type. Of the various grades of bituminous coals, the type known as *coking-coal* is ideal for steelmaking. But for this purpose it must first be converted into *coke.*

To make coke, coal is "baked" by heating it with gas in huge, vertical ovens — air-tight, so the coal will not "burn". The result is a nearly pure carbon.

Gases and smoke from the coking process are collected because they contain highly valuable substances. Gases are purified and stored for many uses. Residue from the smoke, called *coal-tar,* is reheated to obtain a variety of weights of oils. These are distilled for use in the manufacture of thousands of products known in every household. *Here are a few:* Dyes, perfumes, plastics, aspirin, sulpha drugs and other medicines, nylons, tars. So, for good reason, coal is called a "black diamond".

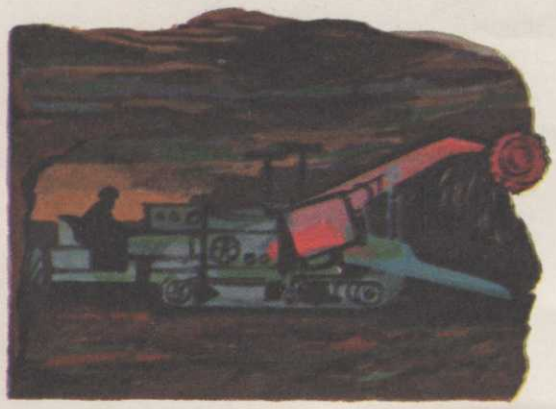
LIMESTONE

is a mineral . . . the third basic ingredient in making iron and steel, and classified chemically by the amount of *calcium* and *magnesium carbonate* it contains. It was formed many millions of years ago by skeletons of coral animals, chemical precipitations and mollusks that piled up in successions of sea bottoms, becoming squeezed together as rock.

It is found in many parts of the world and is plenteous in the U.S.A. Deposits are often miles long and up to thousands of feet in depth. They range from those at or near the earth's surface

to hundreds of feet below. Most limestone used in iron and steelmaking is found at the surface and is mined in what are known as *quarries.*

Dynamited chunks are broken into smaller pieces, then loaded by power machinery for various kinds of transportation to the mills. Here it is stored for further treatment prior to the final use.



SUMMARY

To make **one ton** of iron requires about one and a half tons of ore, one-half ton of coke and one-fifth ton of limestone — two and one-fifth tons total. **Iron ores** are sorted at mills by kinds and degrees of purity prior to dumping into the blast furnace. **Coke,** being a nearly pure, hard carbon, produces the extreme heat needed in the blast furnace. **Limestone,** acts as a scavenger or chemical sponge on the waste materials and impurities to form a "slag" which floats on the liquid molten iron. **Slag is not wasted.** When drawn off, it undergoes treatments for combining it with other materials for myriads of uses such as: bricks and tiles, concrete and cement, insulation, fire-proofing and roofing materials, ceramic ware, mineral wool, macadam and other roadbuilding materials.

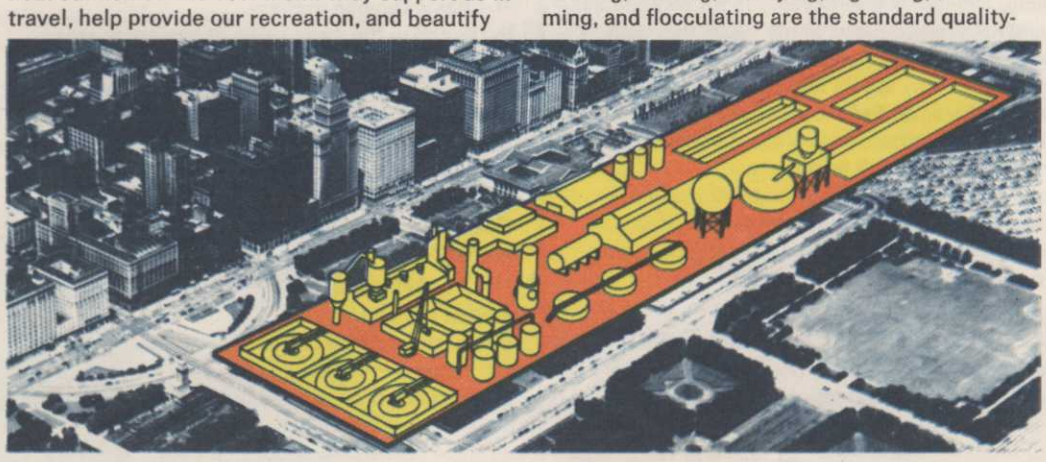
ON AIR AND WATER POLLUTION

We at U.S.Steel share many uses of the life-sustaining resources — air and water — with our community neighbors. Air and water not only help grow material for our clothing and housing — they heat our homes and cool them. They support us in travel, help provide our recreation, and beautify our environment. They also play a substantial part in the manufacturing of U.S.Steel's products that serve mankind and provide our livelihood.

After performing many manufacturing functions, the water we use "goes to the cleaners" before it returns to the natural water supply. Agitating, filtering, settling, clarifying, digesting, skimming, and flocculating are the standard quality-restoring processes of water treatment systems.

The air we use undergoes equally strenuous treatment before it returns to the atmosphere. Washing, filtering, gravity, centrifugal force, precipitation, and vacuum cleaning are some of the ways air is induced to shed the impurities it picks up in manufacturing.

In the 1960s, United States Steel spent one quarter of a billion dollars on air and water pollution control — and is committing hundreds of millions of dollars during the 1970's to further the program. Additionally, to advance the state of technology and engineering in the pollution abatement field, U.S.Steel will continue to spend a great deal of money on research and engineering.



← To illustrate the large amount of space and many types of equipment required for water treatment in just one steel plant this photograph shows a diagram, drawn to scale, of all of the water conservation systems that have been installed since 1966 at U. S. Steel's Gary Works. When these facilities are superimposed on Chicago's Grant Park they stretch from Congress to Randolph Streets and occupy 35 acres.

1974 U.S.A. STEEL INDUSTRY STATISTICS (Source, AISI)

Employment 512,400; Raw steel production 145,494,000 tons (1366 pounds per capita). **METHODS:** Open-hearth 24.4%; Basic Oxygen 56.1%; Electric 19.5%; **TYPES:** Carbon steel 86.9%; Alloy steel 11.6%; Stainless steel 1.5%; **SHIPMENTS:** Automotive 17.3%; Warehouses 21.2%; Construction 16.9%; Machinery 7.6%; Containers 7.5%; Forgings, bolts, screws, etc. 2.4%; Oil & gas industry 3.1%; Appliances & furniture 4.0%; Rail transportation 3.1%; Shipbuilding 1.2%; Miscellaneous and Export 15.7%.